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Heterosis studies in Chilli (*Capsicum annuum* L.) by using CMS lines

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Abstract

The present investigation was carried out to estimate the magnitude of heterosis over mid parent, better parent and standard checks (GAVCH-1) for yield and its contributing traits in chilli (*Capsicum annuum* L.) and developed 30 F_1 hybrids by crossing two lines with fifteen testers using line x tester mating design. The hybrids differed significantly for all the traits studied, as evident from their significant mean square values in all the traits. Among 30 F_1 hybrids, eleven, five and thirteen hybrids exhibited significant positive heterosis for yield per plant over mid parent, better parent, and standard checks, respectively and the hybrid A_1 × GP-18 registered significant standard positive heterosis (106.77 per cent) followed by A_1 × GAVC-112 (67.32 per cent) and A_1 × JC-AV-2019-9-(HP) (64.98%) over check GAVCH-1. Among the 30 hybrids, the hybrid A_1 × GAVC 112 was found to be superior for plant height and number of seeds per fruit, A_1 × JC-AV-2019-6-(SP-R) for fruit girth, A_2 ×JC-AV-2019-5(HP-R) for number of fruits per plant, A_1 × JC-AV-2019-9-(HP) for fresh weight of fruit and dry weight of fruit recorded maximum standard heterosis in desirable direction. The hybrid A_2 × JC-AV-2019-5(HP-R) for days to first fruit ripening, A_1 × GCH-3 for fruit length recorded maximum heterobeltiosis and standard heterosis in desirable direction. The hybrid A_1 × GP-18 was recorded highest magnitude of significant positive heterobeltiosis for yield per plant and capsaicin content. These hybrids can be exploited commercially after multilocation testing and further can be identified for important of yield and its contributing traits through selection of transgressive segregants in F_2 and subsequent generations in chilli.

Keywords: Chilli, Cytoplasmic male sterility, relative heterosis, heterobeltiosis, standard heterosis

Introduction

Chilli (*Capsicum annuum* L.) is an indispensable vegetable cum condiment used in every Indian cuisine due to its pungency, spice, appealing colour and flavour. Development of hybrids for having high productivity and desirable qualities is identified as a key factor to increase the production of chilli in the country. The hybrid seed production is carried out by hand emasculation and pollination. Therefore, the cost of hybrid seeds is comparatively high due to higher labour cost. However, the use of male sterile lines in chilli has been found a effective tool in decreasing the cost of hybrid seed production. Moreover, genetic male sterility (Kumar *et al.*, 2000) [6] and cytoplasmic male sterility (Reddy *et al.*, 2002) [10] systems are also feasible to produce the hybrid seeds on a commercial scale. Heterosis is useful in deciding the direction of future breeding programmes and identifying the cross combinations which are promising in conventional breeding programmes. Therefore, the magnitude of heterosis of the hybrids for yield and its components based on CMS lines was studied.

Materials and Methods

The present investigation was undertaken to estimate heterosis in chilli for twelve characters. Two lines JC-AV-2019-1-(SP) or A_1 and JC-AV-2019-3-(HP) or A_2 and fifteen testers (AVNPC-131, GP-18, GP-21, GP-26, JC-AV-2019-6-(SP-R), JC-AV-2019-5-(HP-R), JC-AV-2019-7-(HP-R), JC-AV-2019-8-(HP), JC-AV-2019-9-(HP), JC-AV-2019-10-(HP), GCH-3, GAVC-112, JCH 785, JCH 787-1 and JCH 802) along with thirty hybrids (developed by line × tester) and one check (GAVCH-1) were evaluated in randomized block design with three replications. The experiment was conducted at Seed Spices Research Station, Jagudan (E_1); Seed Technology, Sardarkrushinagar (E_2) and Potato Research Station, Deesa (E_3), Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar during the *kharif* 2021-2022. Each entry was accommodated in single row of 7.5 m length spaced at 60 cm apart with plant to plant spacing of 60 cm. For *kharif* 2021-22 planting, the seeds were sown in nursery during last week of June 2021. Seedlings were transplanted in the field during third week of August in all the three location (environments).

Statistical analysis

The statistical analysis was done by using average value of selected plants from each genotype and replication in all the three location (environments) for the following aspects. The result of pooled analysis over locations is presented in table 1. Heterosis was estimated as *per cent* increase or decrease in the mean value of F_1 crosses over mid parent *i.e*., relative heterosis Briggle (1963) [2], over better parent *i.e*., heterobeltiosis Fonseca and Patterson (1968) [4] and over standard check *i.e*., standard heterosis Meredith and Bridge (1972) [8] for each character. Hence, the standard heterosis was also worked-out by using standard check hybrid, GAVCH-1**.**

Result and Discussion

The pooled analysis of variance (Table 1) revealed a significant mean square due to environments, genotypes, parents, females, males, females vs. males, parents *vs* hybrids and hybrids for all the traits. Mean square due to hybrids × environments were significant for days to flowering, plant height, fruit length, fruit girth, number of seeds per fruit, dry weight of fruit per plant and ascorbic acid revealing that the hybrids were sensitive to environments. Likewise, the mean square due to (parents vs hybrids) × environments was significant only for days to flowering, days to first fruit ripening, plant height, fruit length, fruit girth, dry weight of fruit per plant, capsaicin content and ascorbic acid indicating the presence of average heterosis for these traits.

The earliest hybrid over mid-parent A_1 × JCH 802 (-14.14%) followed by A_2 × JCH 802 (-11.61%), hybrid over better parent was A_1 × JCH 802 (-22.4%) followed by A_2 × JCH 802 (-21.1%) and hybrid over standard check A_2 ×JC-AV-2019-5(HP-R) (-14.82%) followed by A_2 × JC-AV-2019-10(HP) (-10.15%) for days to flowering. For days to first fruit ripening, the highest desirable heterosis over the mid-parent, better parent and standard check was recorded by the hybrid A_2 × JC-AV-2019-5(HP-R) followed by A_1 × JC-AV-2019-5(HP-R). The majority of the hybrids exhibited significant heterosis in the desired direction and hence this character could be exploited in the new hybrid development programme for earliness. The results were in agreement with reports of Spaldon *et al.* (2015) [12].

The cross combination A_1 × GAVC 112 exhibited the highest magnitude of significant and positive standard heterosis for plant height (40.76%) followed by A_1 × GCH-3 (40.02%) and A_1 × JCH 802 (36.26%). These results were in agreement with reports of Janaki *et al.* (2018) [5], Meena *et al.* (2020) [7] and Rani *et al.* (2021) [9] as they observed significant and positive heterosis for plant height.

The highest significant and positive relative heterosis, heterobeltiosis and standard heterosis for fruit length was recorded in the hybrid A_1 × GCH-3. For fruit girth, the hybrid A_2 × JC-AV-2019-10-(HP) exhibited the highest magnitude of heterobeltiosis (21.37%). The highest desirable standard heterosis was recorded by the hybrid A_1 × JC-AV-2019-6-(SP-R) (202.25%). The results conformed with reports of Vijeth *et al.* (2019) [13], Meena *et al.* (2020) [7] and Rani *et al.* (2021) [9].

For number of fruits per plant, hybrid A_1 × JCH 802 (121.63%) recorded the highest heterobeltiosis followed by A_2 × GP-21 (78.61%) and A_1 × JC-AV-2019-10-(HP) (68.32%). The hybrid A_2 × JC-AV-2019-5-(HP-R) recorded the highest magnitude of standard heterosis (74.15%) followed by A_2 × GP-21 (60.17%) and A_1 × JC-AV-2019-5-(HP-R) (19.63%). The hybrid A_2 × JCH 802 (74.51%), A_1 × JC-AV-2019-10-(HP) (70.47%) and A_2 × GAVC 112 (78.88%) recorded highest significant and positive relative heterosis, heterobeltiosis and standard heterosis, respectively for number of seeds per fruit. The findings were in accordance with the reports of Vijeth *et al.* (2019) [13] and Meena *et al.* (2020) [7] as they reported similar trends for this character.

The highest magnitude of standard heterosis was recorded in the hybrid A_1 × JC-AV-2019-9-(HP) for fresh weight of fruit and dry weight of fruit. The results were in agreement with reports of Abrham *et al.* (2017) [1].

Among 30 hybrids, 11, 5 and 13 hybrids showed significant and positive relative heterosis, heterobeltiosis and standard check for yield per plant, respectively (Table 4). The highest relative heterosis for yield per plant was recorded in the hybrid A_1 × GP-18 (67.81%) followed by A_2 × GP-21 (56.42%) and A_2 × JCH 787-1 (53.11%). The hybrid A_1 × GP-18 (49.34%) recorded. The highest heterobeltiosis followed by A_2 × GP-21 (26.40%) and A_1 × GAVC 112 (20.85%). The hybrid A_1 × GP-18 recorded the highest magnitude of standard heterosis (106.77%) followed by A_1 × GAVC-112 (67.32%) and A_1 × JC-AV-2019-9-(HP) (64.98%). In the present investigation, the hybrids showed significant and positive estimates of heterosis indicating possibilities of its use in a future breeding programme. The results conformed with reports of Spaldon *et al.* (2015) [12], Abrham *et al.* (2017) [1], Vijeth *et al.* (2019) [13], Meena *et al.* (2020) [7] and Rani *et al.* (2021) [9] positive and significant heterosis for yield per plant.

The highest heterobeltiosis for capsaicin content was recorded in the A_1 × GP-18 (30.39%) followed by A_1 × JC-AV-2019-7-(HP-R) (16.26%) and A_2 × JCH 787-1 (12.58%). The results were in agreement with the findings of Chaudhary *et al.* (2013), Sharma *et al.* (2013) and Meena *et al.* (2020) [7] as they reported significant and desired direction heterosis. For ascorbic acid, the hybrid A_2 × JCH 787-1 recorded the highest significant and positive relative heterosis (4.90%) followed by A_1 × GAVC 112 (4.86%) and A_1 × JC-AV-2019-6-(SP-R) (4.75%). A similar trend for ascorbic acid in chilli was also observed by Meena *et al.* (2020) [7].

Table 1: Analysis of variance (mean squares) over environment for different characters in chilli

Source of variation	df	Days to flowering	Days to first fruit ripening	Plant height	Fruits length	Fruit girth	Number of fruits per plant
Rep./Env.	2	12.86	40.48 **	12.81	0.08	0.20 *	26.62
Environment (E)	2	1492.15**	229.87 **	985.18 **	53.07**	39.21 **	295.28 *
Genotypes (G)	46	285.99**	391.23 **	1341.36 **	77.89**	25.82 **	12890.24 **
Parents (P)	16	476.06**	453.72 **	1656.96 **	68.69**	34.77 **	18761.06 **
Females (F)	1	32.00*	346.72 **	1127.18 **	20.12**	133.28 **	16101.75 **
Males (M)	14	531.27**	478.74 **	1796.59 **	74.38**	20.14 **	19728.17 **
F *vs.* M	1	147.21**	210.52 **	231.87 **	37.65**	141.05 **	7880.88 **
P *vs.* F_1	1	3100.37**	2142.53 **	8053.85 **	191.58**	76.96 **	12232.83 **
Hybrids (F_1)	29	84.08**	296.36 **	935.77 **	79.05 **	19.11 **	9673.83 **
G × E	92	19.19**	11.15	57.89 **	6.49 **	0.78 **	105.6
P × E	32	14.11**	8.71	44.00 **	3.25 **	1.17 **	89.13
F×E	2	1.17	1.06	9.59	0.16	0.03	7.66
M×E	28	15.10**	9.83	48.21 **	3.66 **	1.31 **	99.81
(F *vs.* M)×E	2	13.18	0.66	19.50	0.69	0.31 **	21.12
(P *vs.* F_1) × E	2	115.28**	91.12 **	349.76 **	14.72 **	0.17 *	97.01
F_1 × E	58	18.68**	9.75	55.49 **	7.99 **	0.58 **	114.99
Pooled error	276	4.87	8.57	22.98	0.36	0.05	92.81
Source of variation	**df**	**Number of seeds per fruit**	**Fresh weight of fruit per plant**	**Dry weight of fruit per plant**	**Yield per plant**	**Capsaicin content**	**Ascorbic acid**
Rep./Env.	2	50.48	0.01	0.002	10906.92	0.00001	0.09
Environment (E)	2	278.52 **	7.76 **	0.106 **	38795.81**	0.00009 **	3517.5 **
Genotypes (G)	46	5240.38 **	182.65 **	3.279 **	560131.66**	0.00765 **	23598.95 **
Parents (P)	16	3963.90 **	353.91 **	2.435 **	369434.90**	0.01200 **	36609.6 **
Females (F)	1	936.43 **	2193.65 **	2.531 **	112477.07**	0.00569 **	47533.9 **
Males (M)	14	4395.90 **	47.97 **	1.506 **	240138.02**	0.01146 **	31597.93 **
F *vs.* M	1	943.43 **	2797.35 **	15.342 **	2436549.06**	0.02588 **	95848.55 **
P *vs.* F_1	1	20991.93 **	203.07 **	36.768 **	7788202.23**	0.01851 **	95293 **
Hybrids (F_1)	29	5401.49 **	87.45 **	2.59 **	416099.85**	0.00488 **	13948.46 **
G × E	92	52.10 **	0.16	0.013 **	5554.80	0.00010 **	62.49 **
P × E	32	17.39	0.20	0.010 **	3278.50	0.00028 **	43.06 **
F×E	2	3.99	0.69 *	0.008	1515.22	0.00000	14.00
M×E	28	18.33	0.09	0.010 **	3572.59	0.00031 **	45.00 **
(F *vs.* M)×E	2	17.59	1.13 **	0.008	924.59	0.00003 **	44.94 **
(P *vs.* F_1) × E	2	5.34	0.42	0.056 **	5257.49	0.00011 **	123.31 **
F_1 × E	58	72.86 **	0.13	0.014 **	6820.95	0.00001	71.12 **
Pooled error	276	17.58	0.19	0.004	6718.76	0.00001	4.66

*, ** Significant at 5 and 1 per cent levels, respectively

Table 2: Magnitude of heterosis for days to flowering, days to first fruit ripening, plant height and fruit length on pooled basis analysis

Sr. No	Hybrids	Days to flowering			Days to first fruit ripening			Plant height			Fruit length		
		MP	BP	SH	MP	BP	SH	MP	BP	SH	MP	BP	SH
1.	A_1×AVNPC-131	1.04	1.04	0.12	-3.19*	-6.7**	0.26	24.80**	14.28*	34.87 **	-33.67**	-48.50**	-41.27 **
2.	A_1×GP-18	-3.29*	-3.68*	-4.56 **	-6.37**	-9.66**	-2.92 *	10.75*	7.23	35.14 **	0.26	-2.53	17.72 **
3.	A_1×GP-21	-3.08*	-4.03*	-4.9 **	-3.54*	-6.54**	0.43	-0.76	-2.18	15.44 **	-2.82	-12.86*	-0.63
4.	A_1×GP-26	-5.02*	-6.86**	-3.99 **	-4.28*	-7.1**	-0.18	2.03	0.48	18.58 **	9.75*	-3.08	44.28 **
5.	A_1 ×JC-AV-2019-6-(SP-R)	-0.69	-0.92	-1.37	-5.65**	-7.34**	-0.44	-32.64**	-46.73**	-37.14 **	-14.67*	-37.29**	-28.48 **
6.	A_1×JC-AV-2019-5-(HP-R)	-4.93*	-8.98**	-9.81 **	-9.65**	-16.28**	-10.04 **	3.24	-4.83	12.31 *	-4.38	-29.57**	-19.68 **
7.	A_1 ×JC-AV-2019-7-(HP-R)	1.81	0.12	-0.80	-3.59*	-6.7**	0.26	2.92	-17.49*	-2.64	15.17**	1.78	16.09 **
8.	A_1 ×JC-AV-2019-8-(HP)	-0.97	-1.70	-1.14	-1.32	-4.79*	2.32	4.15	-18.59*	-3.94	6.73*	-0.01	14.05 **
9.	A_1 ×JC-AV-2019-9-(HP)	-2.92*	-4.37*	-5.25 **	-4.29*	-8.22**	-1.38	5.44	-9.30	7.04	32.86**	32.30**	52.17 **
10.	A_1 ×JC-AV-2019-10-(HP)	-2.34	-3.91*	-4.79 **	-7.13**	-12.13**	-5.58 **	16.28*	-5.61	11.39 *	25.06**	5.52	20.35 **
11.	A_1×GCH-3	-4.88*	-7.13**	-3.42 **	-4.55*	-7.82**	-0.95	19.18**	18.65*	40.02 **	51.19**	35.44**	54.48 **
12.	A_1×GAVC 112	-5.55**	-5.98**	-6.84 **	-8.6**	-12.21**	-5.67 **	35.76**	19.28*	40.76 **	30.20**	25.97**	43.68 **
13.	A_1×JCH 785	-8.10**	-13.96**	-2.28	-6.3**	-7.54**	2.06	3.75	-3.69	32.68 **	-2.94	-16.87**	-5.20
14.	A_1×JCH 787-1	-7.69**	-8.17**	-9.01 **	-6.22**	-8.62**	-1.81	0.35	-4.54	24.82 **	32.97**	24.04**	41.48 **
15.	A_1×JCH 802	-14.14**	-22.4**	-4.79 **	-9.37**	-12.66**	1.20	45.45**	15.46*	36.26 **	7.76*	-12.19*	0.16
16.	A_2×AVNPC-131	-3.15*	-4.49*	-5.36 **	0.43	-0.09	0.60	31.34**	26.09**	23.72 **	-41.49**	-51.33**	-53.76 **
17.	A_2×GP-18	-3.34*	-4.29*	-5.93 **	-6.97**	-7.33**	-6.70 **	19.76**	2.78	29.53 **	4.01	-7.08*	12.23 **
18.	A_2×GP-21	-4.18*	-4.58*	-7.30 **	-2.26	-2.3	-1.55	14.07*	1.96	16.87 **	0.31	-2.08	-6.97 *
19.	A_2×GP-26	-5.55**	-8.63**	-5.82 **	-1.74	-1.95	-0.87	10.19	-1.44	12.78 **	-7.16*	-23.95**	13.21 **
20.	A_2 ×JC-AV-2019-6-(SP-R)	-3.61*	-5.15*	-5.59 **	-2.94	-4.3*	-0.87	11.15	-2.17	-11.68 *	27.64**	-0.18	-5.16
21.	A_2×JC-AV-2019-5-(HP-R)	-8.90**	-11.60**	-14.82 **	-15.92**	-19.68**	-19.13 **	13.03*	7.77	7.29	29.84**	1.79	-3.29
22.	A_2 ×JC-AV-2019-7-(HP-R)	-1.72	-2.01	-5.59 **	0.26	0.17	0.86	33.67**	19.54*	7.93	16.02**	11.45*	5.91

23.	A_2 ×JC-AV-2019-8-(HP)	-1.45	-3.51*	-2.97 *	0.30	-0.09	0.60	30.02**	12.87	1.90	9.12*	6.58	6.22 *
24.	A_2 ×JC-AV-2019-9-(HP)	-4.27*	-4.38*	-7.87 **	-2.41	-3.41	-2.75 *	2.85	-0.16	-9.86 *	-4.20	-12.52*	0.62
25.	A_2 ×JC-AV-2019-10-(HP)	-6.52**	-6.75**	-10.15 **	-5.41*	-7.67**	-7.04 **	24.35**	12.84	1.88	-23.26**	-29.97**	-33.46 **
26.	A_2×GCH-3	-5.98**	-9.43**	-5.82 **	-1.84	-2.13	-1.47	27.65**	13.09*	32.27 **	-20.98**	-22.94**	-26.79 **
27.	A_2×GAVC 112	-3.05*	-3.95*	-5.70 **	0.60	-0.26	0.43	5.21	4.67	-5.51	11.40*	5.33	12.34 **
28.	A_2×JCH 785	-7.01**	-14.06**	-2.40	-3.94*	-8.16**	1.37	3.73	-14.15*	18.28 **	27.46**	18.26**	12.38 **
29.	A_2×JCH 787-1	-5.22*	-6.05**	-7.87 **	-5.54*	-6.14*	-4.30 **	9.05	-7.83	20.51 **	21.11**	18.83**	17.34 **
30.	A_2×JCH 802	-11.61**	-21.10**	-3.19 *	-5.35**	-11.55**	2.49	41.62**	25.20*	13.04 **	4.81	-7.98	-12.57 **
S.Em±		0.86	0.99	1.27	1.28	1.48	1.67	1.93	2.23	2.74	0.25	0.29	0.34
Min.		-14.14	-22.40	-14.82	-15.92	-19.68	-19.13	-32.64	-46.73	-37.14	-41.49	-51.33	-53.76
Max.		1.81	1.04	0.12	0.60	0.17	2.49	45.45	26.09	40.76	51.19	35.44	54.48
No. of positive significant		0	0	0	0	0	0	15	8	19	16	7	15
No. of negative significant		23	25	24	20	22	9	1	4	3	6	12	8

*, ** Significant at 5 and 1 per cent levels, respectively

Table 3: Magnitude of heterosis for fruit girth, number of fruits per plant, number of seeds per fruit and fresh weight of fruit on pooled basis analysis

Sr. No	**Hybrids**	**Fruit girth**			**Number of fruits per plant**			**Number of seeds per fruit**			**Fresh weight of fruit**		
		MP	**BP**	**SH**	**MP**	**BP**	**SH**	**MP**	**BP**	**SH**	**MP**	**BP**	**SH**
1.	A_1×AVNPC-131	-24.16**	-42.09**	56.15 **	37.37**	-10.57	-16.24 **	-100.00**	-100.00**	-100.00 **	-55.64**	-73.92**	29.74 **
2.	A_1×GP-18	-13.64**	-40.16**	61.35 **	80.75**	19.22*	5.64	65.38**	59.51**	30.30 **	-35.28**	-60.07**	98.67 **
3.	A_1×GP-21	-12.49**	-37.93**	67.35 **	45.63**	-4.22	-14.11 **	20.80**	9.46	2.26	-39.17**	-64.74**	75.43 **
4.	A_1×GP-26	-17.01**	-42.06**	56.21 **	49.33**	9.07	-33.07 **	31.74**	0.07	46.25 **	-40.78**	-63.41**	82.01 **
5.	A_1 ×JC-AV-2019-6-(SP-R)	18.77**	12.10**	202.25 **	58.11*	45.41*	-58.88 **	37.90**	29.18**	12.22 **	-36.77**	-55.78**	119.99 **
6.	A_1×JC-AV-2019-5-(HP-R)	-26.26**	-52.94**	26.90 **	11.56*	-35.75**	19.63 **	33.62**	9.85*	29.42 **	-54.68**	-75.49**	21.96 **
7.	A_1 ×JC-AV-2019-7-(HP-R)	-23.29**	-44.10**	50.71 **	32.23*	-1.66	-42.94 **	55.51**	49.67**	22.80 **	-46.13**	-69.03**	54.06 **
8.	A_1 ×JC-AV-2019-8-(HP)	-7.79*	-36.76**	70.51 **	69.24**	42.67*	-41.19 **	59.05**	34.92**	2.39	-42.71**	-65.43**	71.98 **
9.	A_1 ×JC-AV-2019-9-(HP)	-3.19	-28.63**	92.44 **	20.62	-14.17	-42.65 **	63.21**	41.49**	46.32 **	-11.35**	-43.72**	180.00 **
10.	A_1 ×JC-AV-2019-10-(HP)	-9.68**	-36.67**	70.75 **	99.44**	68.32**	-30.80 **	71.54**	70.47**	29.37 **	-51.27**	-70.40**	47.27 **
11.	A_1×GCH-3	-11.88**	-40.89**	59.37 **	-4.29	-41.42**	-26.10 **	55.17**	47.96**	12.29 **	-27.91**	-58.98**	104.07 **
12.	A_1×GAVC 112	-6.02*	-35.14**	74.89 **	10.74	-30.41**	-23.36 **	27.95**	-4.48	47.04 **	-25.67**	-56.43**	116.73 **
13.	A_1×JCH 785	-5.82*	-32.94**	80.83 **	22.16*	-15.85*	-36.99 **	12.41*	-11.25*	16.31 **	-23.86**	-53.48**	131.44 **
14.	A_1×JCH 787-1	-15.54**	-34.32**	77.10 **	33.65*	16.64	-55.75 **	32.04**	2.50	40.77 **	-32.82**	-57.07**	113.57 **
15.	A_1×JCH 802	-10.37**	-43.29**	52.90 **	147.56**	121.63**	-20.71 **	37.42**	1.81	-22.75 **	-47.66**	-70.07**	48.89 **
16.	A_2×AVNPC-131	-39.45**	-43.13**	-19.15 **	-11.19	-16.42*	-21.72 **	-100.00**	-100.00**	-100.00 **	-8.24*	-25.16**	3.64
17.	A_2×GP-18	8.92*	-0.17	24.68 **	13.23*	9.41	-3.06	50.45**	37.49**	35.67 **	4.10	-4.19	32.67 **
18.	A_2×GP-21	5.10	0.02	24.92 **	85.92**	78.61**	60.17 **	14.23*	11.18*	9.71 **	-18.07**	-35.58**	-10.81 **
19.	A_2×GP-26	4.32	-3.22	20.87 **	6.93	-6.82	-23.02 **	28.44**	7.58*	57.22 **	10.03*	1.60	40.69 **
20.	A_2 ×JC-AV-2019-6-(SP-R)	-0.84	-24.55**	80.59 **	4.34	-32.84**	-44.52 **	45.54**	36.83**	35.02 **	1.35	-13.95**	70.68 **
21.	A_2×JC-AV-2019-5-(HP-R)	14.61*	-8.50*	14.28 **	29.57**	-6.47*	74.15 **	26.14**	15.89**	36.55 **	-26.09**	-52.18**	-33.79 **
22.	A_2 ×JC-AV-2019-7-(HP-R)	7.58*	6.91	33.52 **	-13.62	-26.48**	-39.26 **	53.58**	40.64**	38.78 **	14.96*	-11.59*	22.43 **
23.	A_2 ×JC-AV-2019-8-(HP)	11.12*	0.14	25.06 **	8.69	-18.54*	-32.70 **	51.35**	16.22*	14.68 **	-3.10	-15.55**	16.93 **
24.	A_2 ×JC-AV-2019-9-(HP)	10.02*	8.71*	39.07 **	-3.08	-12.35	-27.59 **	59.86**	56.20**	61.53 **	7.36*	5.72	46.38 **
25.	A_2 ×JC-AV-2019-10-(HP)	29.90**	21.37**	51.57 **	27.41*	-4.60	-21.18 **	57.82**	38.84**	37.00 **	-20.28**	-29.34**	-2.17
26.	A_2×GCH-3	-3.43	-16.11**	4.76	-2.07	-18.97**	2.23	40.55**	19.30**	17.72 **	-15.41*	-36.73**	-12.40 **
27.	A_2×GAVC 112	10.03*	0.19	25.12 **	6.10	-7.15	2.27	41.62**	16.19**	78.88 **	-9.91*	-27.09**	0.96
28.	A_2×JCH 785	12.15*	7.43	34.17 **	34.21**	27.92**	5.70	10.20*	-3.42	26.58 **	4.43	-6.12	30.00 **
29.	A_2×JCH 787-1	12.30**	2.98	54.20 **	52.48**	11.24	-8.09	29.77**	11.50*	53.13 **	2.45	2.40	41.79 **
30.	A_2×JCH 802	16.68**	-8.23*	14.60 **	66.04**	18.97*	-1.71	74.51**	19.58**	18.00 **	-16.64**	-36.81**	-12.51 **
S.Em±		0.10	0.11	0.12	3.45	3.99	5.52	1.66	1.91	1.76	0.18	0.20	0.25
Min.		-39.45	-52.94	-19.15	-13.62	-41.42	-58.88	-100.00	-100.00	-100.00	-55.64	-75.49	-33.79
Max.		29.90	21.37	202.25	147.56	121.63	74.15	74.51	70.47	78.88	14.96	5.72	180.00
No. of positive significant		11	3	28	19	8	3	28	21	25	3	0	23
No. of negative significant		14	19	1	0	10	20	2	3	3	22	25	4

*, ** Significant at 5 and 1 per cent levels, respectively

Table 4: Magnitude of heterosis for dry weight of fruit, yield per plant, capsaicin content and ascorbic acid on pooled basis analysis

Sr. No	Hybrids	Dry weight of fruit			Yield per plant			Capsaicin content			Ascorbic acid		
		MP	BP	SH	MP	BP	SH	MP	BP	SH	MP	BP	SH
1.	A_1×AVNPC-131	3.06	-24.30**	89.01 **	-1.47	-21.16*	9.16	15.67**	-8.26**	-38.89 **	-5.73**	-29.58**	-68.12 **
2.	A_1×GP-18	13.77**	-21.21**	96.72 **	67.81**	49.34**	106.77 **	62.11**	30.39**	-16.34 **	4.24**	-32.43**	-49.02 **
3.	A_1×GP-21	44.65**	4.31*	160.44 **	44.87**	9.49	51.60 **	4.86*	-14.96**	-46.62 **	-4.19**	-33.33**	-61.94 **
4.	A_1×GP-26	36.78**	5.13*	162.48 **	16.15	-11.53	22.49 **	27.68**	2.13	-33.50 **	-4.07**	-39.10**	-49.49 **
5.	A_1 ×JC-AV-2019-6-(SP-R)	0.92	-7.49*	130.96 **	-2.06	-34.30**	-9.04	-3.23*	-20.44**	-51.78 **	4.75**	-25.10**	-61.05 **
6.	A_1×JC-AV-2019-5-(HP-R)	6.49*	-37.38**	56.35 **	33.63**	5.23	45.71 **	-4.70**	-34.64**	-31.34 **	-1.33	-40.17**	-37.12 **
7.	A_1 ×JC-AV-2019-7-(HP-R)	-4.20	-34.2**	64.29 **	-3.63	-36.75**	-12.44	41.60**	16.26**	-29.28 **	3.06*	-30.55**	-55.34 **
8.	A_1 ×JC-AV-2019-8-(HP)	14.32**	-24.57**	88.33 **	12.49	-26.46*	1.83	3.17*	-24.87**	-35.73 **	-1.85*	-37.32**	-49.43 **
9.	A_1 ×JC-AV-2019-9-(HP)	46.83**	18.89**	196.83 **	42.12**	19.16*	64.98 **	-2.52	-3.87	-61.39 **	1.26	-5.99*	-75.46 **
10.	A_1 ×JC-AV-2019-10-(HP)	-6.39*	-28.47**	78.58 **	11.92	-26.26*	2.11	-14.00**	-37.64**	-45.89 **	2.61*	-35.13**	-45.14 **
11.	A_1×GCH-3	65.93**	0.41	150.69 **	35.67**	10.20	52.58 **	5.45**	-25.25**	-30.12 **	-1.61*	-38.83**	-43.78 **
12.	A_1×GAVC 112	52.04**	5.81*	164.18 **	43.65**	20.85*	67.32 **	13.56**	-11.69**	-37.89 **	4.86**	-28.94**	-55.27 **
13.	A_1×JCH 785	16.62**	-15.08**	112.02 **	31.99**	5.73	46.39 **	-4.38*	-19.65**	-53.89 **	-2.58*	-32.05**	-61.53 **
14.	A_1×JCH 787-1	35.71**	8.90**	171.89 **	-0.87	-31.51**	-5.18	-0.44	-18.32**	-50.23 **	0.40	-32.00**	-57.11 **
15.	A_1×JCH 802	11.53**	-25.98**	84.81 **	45.45**	-14.06	18.98 **	-14.17**	-17.28**	-65.17 **	0.84	-27.35**	-63.16 **
16.	A_2×AVNPC-131	-33.98**	-44.66**	-4.20	-17.62	-29.03*	-18.42 **	5.94**	-1.83	-34.62 **	-1.26	-11.81**	-49.22 **
17.	A_2×GP-18	19.49**	-7.07*	60.89 **	15.98	12.47	29.29 **	-35.26**	-38.96**	-60.84 **	3.83**	-8.47**	-30.94 **
18.	A_2×GP-21	5.64	-13.49**	49.78 **	56.42**	26.40*	45.31 **	8.13**	3.01*	-35.34 **	-1.48	-1.89*	-43.51 **
19.	A_2×GP-26	-10.41*	-20.50**	37.65 **	16.21	-5.27	8.90	-10.62**	-16.30**	-45.50 **	1.02	-14.43**	-29.03 **
20.	A_2 ×JC-AV-2019-6-(SP-R)	33.43**	22.23**	154.31 **	16.30	-17.92	-5.65	-5.49**	-8.43**	-44.50 **	-12.04**	-16.29**	-51.81 **
21.	A_2×JC-AV-2019-5-(HP-R)	9.56*	-31.30**	18.94 **	16.13	-1.72	12.98	-22.03**	-39.93**	-36.89 **	-0.71	-23.16**	-19.24 **
22.	A_2 ×JC-AV-2019-7-(HP-R)	-7.32*	-28.68**	23.47 **	-5.55	-35.00**	-25.28 **	-1.32	-4.57*	-41.95 **	-11.1**	-15.75**	-45.82 **
23.	A_2 ×JC-AV-2019-8-(HP)	-2.02	-28.42**	23.93 **	0.49	-31.14*	-20.85 **	-3.24*	-19.48**	-31.12 **	-1.77*	-15.84**	-32.09 **
24.	A_2 ×JC-AV-2019-9-(HP)	19.47**	13.10**	95.81 **	2.14	-7.30	6.57	9.16**	-6.84**	-47.06 **	-4.96**	-30.93**	-60.24 **
25.	A_2 ×JC-AV-2019-10-(HP)	-15.39**	-25.47**	29.03 **	-2.86	-32.84*	-22.80 **	5.30**	-12.87**	-24.39 **	3.20**	-13.26**	-26.65 **
26.	A_2×GCH-3	3.52	-32.55**	16.79 **	-10.78	-21.83*	-10.14	-5.91**	-24.36**	-29.28 **	-3.86**	-21.82**	-28.15 **
27.	A_2×GAVC 112	17.49**	-8.06*	59.19 **	-1.05	-9.85	3.64	-1.18	-10.66**	-37.17 **	4.12**	-0.32	-37.26 **
28.	A_2×JCH 785	4.82	-13.10**	50.46 **	37.60**	18.69*	36.44 **	-17.61**	-18.01**	-52.95 **	-5.83**	-6.61**	-46.23 **
29.	A_2×JCH 787-1	22.00**	14.21**	97.74 **	53.11**	11.77	28.48 **	16.51**	12.58**	-31.39 **	4.90**	0.32	-36.71 **
30.	A_2×JCH 802	13.17*	-16.70**	44.22 **	25.04	-23.8*	-12.42	-4.77*	-17.11**	-52.89 **	-3.2**	-8.97**	-47.59 **
S.Em±		0.03	0.03	0.04	45.07	45.07	46.82	0.001	0.001	0.001	0.80	0.92	1.26
Min.		-33.98	-44.66	-4.20	-17.62	-36.75	-25.28	-35.26	-39.93	-65.17	-12.04	-40.17	-75.46
Max.		65.93	22.23	196.83	67.81	49.34	106.77	62.11	30.39	-16.34	4.90	0.32	-19.24
No. of positive significant		18	8	29	11	5	13	13	4	0	9	0	0
No. of negative significant		5	21	0	0	12	4	13	23	30	13	28	30

*, ** Significant at 5 and 1 per cent levels, respectively

Conclusion

In the present investigation, the magnitude of heterosis varied from hybrid to hybrid for all the characters under study. Such type of results revealed that the selection of parents has an important bearing on the performance of any hybrid. In chilli, higher vigour of yield is more important. The hybrids A_1 × GP-18, A_1 × GAVC 112 and A_1 × JC-AV-2019-9-(HP) were found promising based on the significant heterosis over mid-parent, better parent as well as standard check (GAVCH-1) for yield per plant. The hybrids also reported significant heterosis for one or more yield contributing traits like fruit length, fruit girth, number of fruits per plant, number of seeds per fruit, dry weight of fruit per plant and capsaicin content. These hybrids can be exploited commercially after multiloclation testing and further can be identified for important of yield and its contributing traits through selection of transgressive segregants in F_2 and subsequent generations in chilli.

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